Supplementary Material for:
B. P. Weiss et al.
Reply to Comment on "Pervasive remagnetization of detrital zircon host rocks in the Jack Hills, Western Australia and implications for records of the early dynamo"
Earth and Planetary Science Letters

Sampling site of EHJH blocks. B. Weiss and J. Kirschvink collected the three EHJH blocks in the Jack Hills in 2001 with R. Pidgeon, T. M. Harrison, and S. Mojzsis; the first is the co-discoverer of the Erawandoo Hill Hadean zircon original discovery outcrop (Compston and Pidgeon, 1986) and all three have studied the outcrop extensively (Bell et al., 2015; Compston and Pidgeon, 1986; Dunn et al., 2005; Grange et al., 2010; Harrison, 2009; Holden et al., 2009; Hopkins et al., 2008; Hopkins et al., 2010; Kemp et al., 2010; Mojzsis, 2007; Mojzsis et al., 2001; Pidgeon, 1992, 2014; Pidgeon and Wilde, 1998; Spaggiari et al., 2007; Trail et al., 2016; Trail et al., 2011; Turner et al., 2007; Turner et al., 2004; Watson and Harrison, 2005; Wilde and Pidgeon, 1990)] (Fig. S2 and Table S4). Furthermore, we have extracted >4 Ga zircons from blocks within 5 m of the EHJH6 and EHJH7 sites. This context negates the speculation of Bono et al. (2016) and Cottrell et al. (2016) that the EHJH samples are not from the Erawandoo Hill Hadean zircon outcrop.

Ferromagnetic mineralogy of Erawandoo Hill metaconglomerates. Weiss et al. (2015) provided five pieces of evidence for pyrrhotite as the dominant ferromagnetic mineral (along with some goethite and hematite) in both the clasts and much of the matrix of the Jack Hills metaconglomerates: (a) thermal demagnetization of three-axis isothermal remanent magnetization, showing a mineral with a Curie point of ~325°C and coercivity exceeding 0.36 T (their Figs. 2 and S2); (b) thermal demagnetization of natural remanent magnetization, showing maximum unblocking temperatures usually below 320-340°C; (c) identification of monoclinic pyrrhotite's 34 K Besnus transition in low-temperature magnetometry measurements (their Fig. 3H); (d) quantitative measurements of sulfides using wavelength dispersive spectroscopy showing Fe:S in the pyrrhotite field (their Fig. 4c); (e) backscattered electron microscopy imaging of iron sulfides identified with energy dispersive spectroscopy (EDS) (their Fig. 4a). Cottrell et al. (2016) also observed maximum unblocking temperatures of 320-340°C in the Erawandoo Hill metaconglomerate, but concluded that Cr-Fe spinels are the dominant remanence carrier. However, their compositional analyses only included EDS, such that they did not show quantitatively that the composition of the spinels is consistent with the observed unblocking temperatures. Given the aforementioned evidence for pyrrhotite and the fact that Cr-Fe spinels with ~325°C Curie points are only very rarely found to be dominant remanence carriers in terrestrial rocks (Moskowitz et al., 2015), we suggest that monoclinic pyrrhotite is a better candidate as the main remanence carrier in the samples of Cottrell et al. (2016).

Calculation of mean directions. As discussed in the main text, we calculate a mean for each EHJH5, EHJH6, and EHJH7 block. These consist of clast high temperature (HT) directions from EHJH5 and clast and matrix HT directions from EHJH6 and EHJH7. Following Weiss et al. (2015), we use the HT mean direction inferred for each clast that yielded multiple intra-clast specimens for EHJH5, while we considered each intra-clast specimen as a direction due to the small total number of specimens measured for EHJH7 (although using the clast means would not meaningfully change the results). Because a quantile-quantile test (Tauxe, 2010) shows that the EHJH6 directions are collectively non-Fisherian (Table S1), we calculate a mean direction following Kent (1982) using PmagPy (Tauxe et al., 2016) (Table S2). As discussed in the main text, the directions of EHJH6 appear to be streaked between two directions that may be associated with multiple remagnetization episodes that are contributing to the distinct sample directions as well as the block mean. All the other Jack Hills combined sites shown in Fig. 1B have distributions consistent with being Fisherian (Table S1).

One might argue that we should calculate a grand EHJH5-7 mean using all of 62 specimens from all blocks rather than the approach here of calculating a grand mean from the 3 EHJH block means. This alternate approach would produce a mean very similar to that originally reported by Weiss et al. (2015) but with a much smaller confidence interval. We chose not to follow this approach since Fig. 1A shows that there are clear systematic directional offsets between the three blocks. In any case, both approaches yield the same overall result that the metasediment and monzogranite grand mean is within error of the Warakurna LIP mean (Fig. 1B).

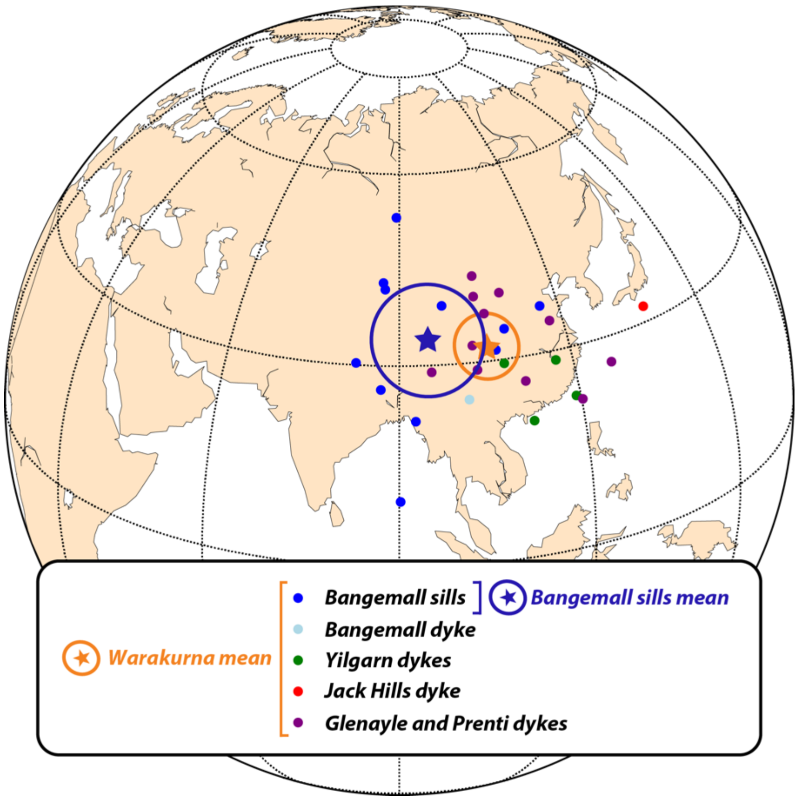

Fig. S1. Virtual geomagnetic poles (VGPs) inferred from 1.1 Ga western Australian dykes and sills associated with the Warakurna LIP. Data and references are provided in Table S3 with the following identification numbers: Bangemall sills (blue circles) = 1-11, Bangemall dyke (light blue circle) = 12, Yilgarn dykes (green circles) = 13-16; Jack Hills dyke = 17, Glenayle and Prenti dykes (purple circles) = 18-28. Stars show mean poles for all Warakurna rocks (orange) and mean pole for just Bangemall sills (blue) [the latter was used as the Warakurna mean direction in Weiss et al. (2015)]. The Jack Hills dike VGP is at the edge of the population of Warakurna VGPs likely due to secular variation.

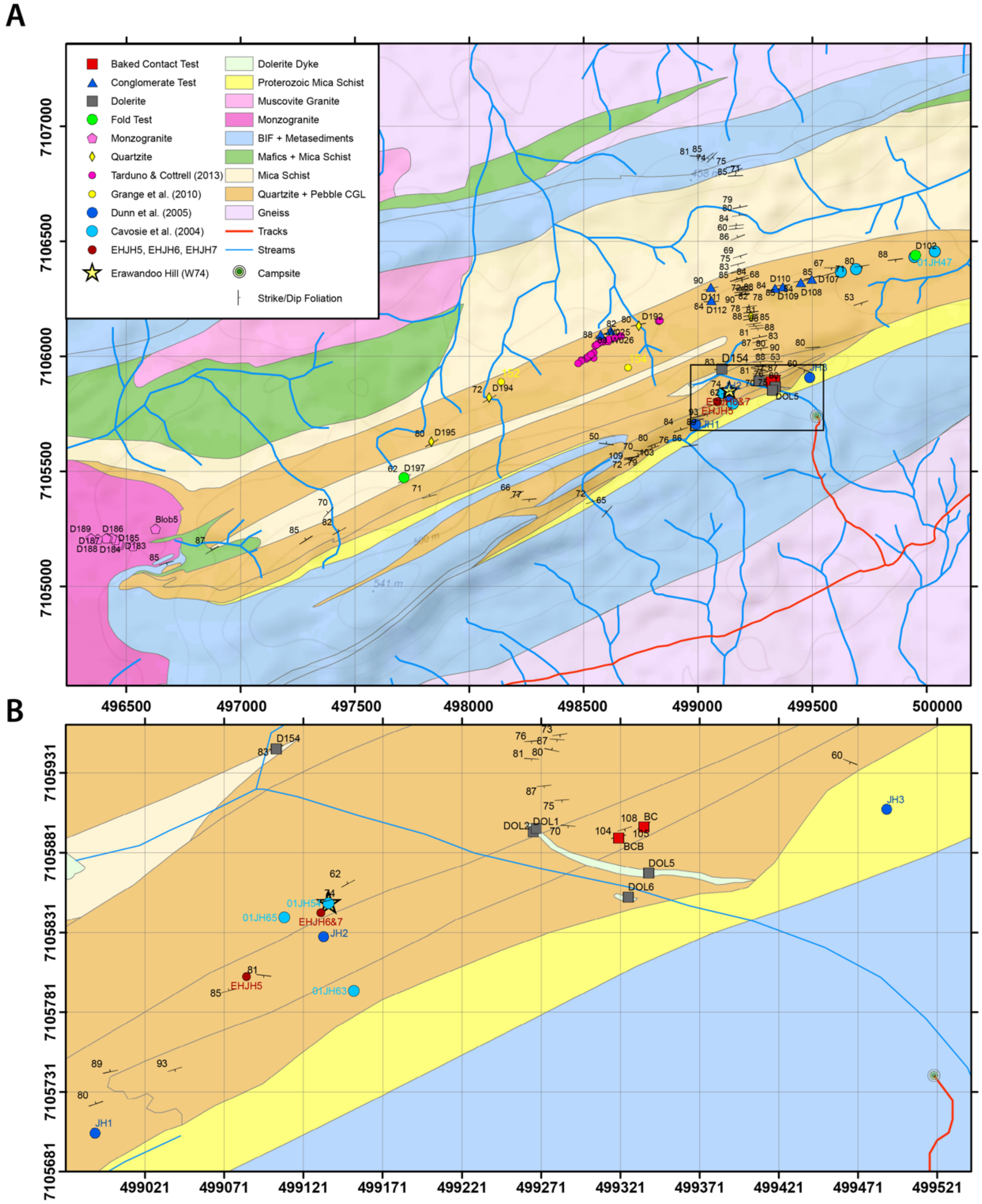

Fig. S2. Generalized geological map of the central-west Jack Hills after Spaggiari (2007). Lithologies are denoted by light shaded colors. Our baked contact, fold, and conglomerate test sites are noted. Yellow star denotes discovery site of Hadean (i.e., >4 Ga) zircons (W74, on Erawandoo Hill). Sampling locations of Cavosie et al. (2004), Dunn et al. (2005), and Grange et al. (2010) are denoted by small light blue, dark blue and yellow circles. Sampling localities for individual cobbles sampled by Tarduno and Cottrell (2013) are shown by small magenta circles. All geological contacts are estimated. Stratigraphic up direction frequently is ambiguous within the quartzites and conglomerates, but is usually toward the southeast. Short lines show strike direction with dip toward short perpendicular line and dip angle given in degrees. Magnetic declination was set to 0°; the estimated local magnetic declination was 0.4°. Projection is with the Universal Transverse Mercator grid in the World Geodetic System 1984 standard. Elevation difference between contour lines (grey) is 50 m. Global Positioning System coordinates for our sites are given in Table S4. (A) Overview map. Spacing between gridlines is 500 m. (B) Zoom into Erawandoo Hill Hadean zircon original discovery outcrop [boxed region in (A)]. Spacing between gridlines is 50 m. Hadean zircons previously have been isolated from sites JH1, JH2 and JH3 by Dunn et al. (2005), site 152 by Grange et al. (2010), and from sites 01JH36, 01JH54, 01JH65, and W74 by Cavosie et al. (2004). The positions of the three EHJH sites plotted differ by ~200 m from those in Weiss et al. (2015) Fig. 1 due to a minor datum conversion error in the latter study. The original plotting positions of these sites were nevertheless within just 16-61 m of the Hadean zircon site JH1.

Tables

Table S1. Tests for Fisher distribution of overprint directions in the Jack Hills.

Sites	*N*	M_u	Fisherian?	M_e	Fisherian?
Conglomerate test HT (block EHJH5)	30	1.168	yes	0.544	yes
Conglomerate test HT (block EHJH6)	22	1.369	no	0.865	yes
Conglomerate test HT (block EHJH7)	10	0.773	yes	0.793	yes
Dike (dolerite from sites BC, BCB, and D154)	12	0.704	yes	1.003	yes
Monzogranite HT (sites D182-188, Blob4, and Blob5)	19	1.070	yes	0.874	yes
Country rock HT (sites D192, D194, and D195)	10	1.168	yes	0.685	yes
Baked contact test HT (site D154)	10	0.832	yes	0.667	yes
Baked contact test HT (site BC)	10	0.914	yes	0.731	yes
Baked contact test HT (site BCB)	12	0.975	yes	0.902	yes

Note: The first column gives the site name, the second column gives the number of directions, the third and fifth columns give the statistics that test for uniform distribution in declination and exponential distribution in inclination, respectively, around the mean, the fourth and sixth columns show whether a Fisher distribution can be rejected with 95% confidence based on each statistic (i.e., M_u and M_e exceed critical values of 1.207 and 1.094, respectively). Using measurements from Weiss et al. (2015). Note that the EHJH5, EHJH6, and EHJH7 values differ from those reported by Bono et al. (2016).

Table S2. Mean overprint directions for Jack Hills rocks.

Sites	δ (°)	i (°)	α_{95} (°) or η, ζ (°)	*N*	Reference
Conglomerate test HT (block EHJH5)	332.3	12.3	7.9	30	Weiss et al. (2015)
Conglomerate test HT (block EHJH6)	312.0	72.5	10.5, 24.8	22	Weiss et al. (2015), This study
Conglomerate test HT (block EHJH7)	342.6	-6.2	21.1	10	Weiss et al. (2015)
Dike (dolerite from sites BC, BCB, and D154)	19.3	47.5	10.1	12	Weiss et al. (2015)
Monzogranite HT (sites D182-188, Blob4, and Blob5)	358	51.9	11.7	19	Weiss et al. (2015)
Country rock HT (sites D192, D194, and D195)	9.3	61.2	8.8	10	Weiss et al. (2015)
Fold test at site MT (site D197)	345.8	21.0	32.0	5	Weiss et al. (2015)
Baked contact test HT (site D154)	45.0	45.5	19.5	13	This study
Baked contact test HT (site BC)	28.0	62.0	20.2	10	This study
Baked contact test HT (site BCB5)	40.9	38.7	20.2	12	This study
*Grand mean of metasediments and monzogranite**	*0.8*	*43.9*	*23.1*	*9*	*This study*

Note: The first column lists the site or block, the second and third columns are the declination and inclination of the mean direction (Kent mean for the EHJH6 block and Fisher means for all other sites), the fourth column gives the of the sizes of the 95% confidence interval semiaxes of the Kent ellipse for the EHJH6 block and the radius of the Fisher circle for all other sites, the fifth column gives the number of directions, and the sixth column lists the reference for the reported mean. HT component ranges are defined in Weiss et al. (2015).
*Using all site means in this table except that of the dike.

Table S3. Site mean directions for igneous rocks associated with the Warakurna LIP.

ID	Site	Site λ (°)	Site θ (°)	Dip Direction (°)	Dip (°)	N	δ_{geo} (°)	i_{geo} (°)	k	α_{95} (°)	δ_{tilt} (°)	i_{tilt} (°)	VGP λ (°)	VGP θ (°)	Reference	δ_{geo} at JH (°)	i_{geo} at JH (°)
1	BBS-1	-23.5	116.6	88	13	9	344.9	48.4	75	5.6	359.8	48.7	36.8	116.4	Wingate et al. (2002)	359.5	45.6
2	BBS-3	-23.7	116.6	353	4	5	336.4	37.7	108	6.6	337.2	33.9	42.3	86.9	Wingate et al. (2002)	337.3	30.0
3	BBS-5	-23.8	116.7	134	1	5	328.5	50.5	610	2.8	328.5	51.5	26.5	87	Wingate et al. (2002)	329.0	49.0
4	BBS-6	-23.8	116.7	320	2	8	337.4	37.1	41	8.2	337	35.2	41.3	87.3	Wingate et al. (2002)	337.1	31.7
5	BBS-7	-23.8	116.6	41	60	6	267.9	49.3	37	10.1	352.4	50.6	34.4	108.8	Wingate et al. (2002)	352.3	47.9
6	BBS-8	-23.9	116.9	29	29	6	312.1	57.7	257	3.8	343.7	42.9	38.7	97.9	Wingate et al. (2002)	344.0	39.9
7	BBS-9	-23.9	116.8	233	19	6	344.7	40.9	97	6.2	327.2	45.2	30.3	82.7	Wingate et al. (2002)	327.7	42.6
8	BBS-10	-23.4	116.2	28	43	6	268.1	65.3	575	2.6	350.2	53.8	31.5	106.7	Wingate et al. (2002)	349.8	50.8
9	BBS-12	-23.8	116.6	34	80	5	244.8	22.6	195	4.9	331	58	21.9	92.6	Wingate et al. (2002)	331.6	55.9
10	BBS-15	-23.9	116.6	205	74	4	2.8	5.1	20	18.1	319.9	65.2	10.1	90.2	Wingate et al. (2002)	320.9	63.7
11	BBS-25	-23.7	115.6	38	79	11	111.3	-37.5	40	6.9	164.1	-19.9	52.6	89.3	Wingate et al. (2002)	343.5	14.9
12	BBS-dyke	-22.2	116.3			9	341.9	60	159	4.1			24.7	101.3	Wingate et al. (2002)	342.2	56.4
13	MKTI	-26.2	117.3			7	359.1	54.7	102	6			29.4	107.8	Wingate et al. (2004)	350.4	53.2
14	MKTJ	-26.2	117.0			6	2.6	60	49	9.7			20.5	111.5	Wingate et al. (2004)	353.0	61.8
15	MKTK	-26.2	117.1			7	352.9	61.8	27	11.7			22.9	119.2	Wingate et al. (2004)	2.8	60.0
16	MKTM	-23.2	117.7			8	350.1	53.2	143	4.6			28.6	116.9	Wingate et al. (2004)	360.0	54.7
17	JH dike	-26.2	117.0			11	19.3	47.5	18	10.1			32.2	137	Weiss et al. (2015)	19.3	47.4
18	A	-25.4	122.3	35	2	7	345.3	43.8	99	6.1	346.7	42.5	37	105.6	Wingate (2003)	350.0	44.2
19	B	-25.0	121.6			6	333.4	49.6	75	7.8			29	95.4	Wingate (2003)	338.9	50.3
20	C	-25.1	121.7			8	345.3	40.6	85	6			39.7	104.1	Wingate (2003)	349.3	40.4
21	D	-25.2	121.9			10	346.5	36.2	190	3.5			42.8	104.5	Wingate (2003)	350.3	36.1
22	E	-25.1	122.0			6	340.2	52.4	446	3.2			28.9	103.1	Wingate (2003)	345.5	52.8
23	FG	-25.2	122.2	5	5	8	344.6	61.4	90	5.9	347.3	56.7	26.4	111	Wingate (2003)	353.3	56.5
24	H	-25.2	122.5			5	357.1	61.4	109	7.4			22.2	120.2	Wingate (2003)	4.0	60.5
25	I	-25.2	122.5			8	5.0	57.7	208	3.9			26.3	126.9	Wingate (2003)	11.1	56.1
26	J	-25.3	122.1	35	5	6	336.4	51.2	38	11	341.3	48.4	32.5	102.7	Wingate (2003)	346.2	48.8
27	K	-24.9	121.6			6	356.1	49.7	15	17.9			34.4	117.5	Wingate (2003)	0.5	48.4
28	L	-26.5	122.8	35	4	4	346.1	42.3	34	16	348.7	39.6	39.8	109.2	Wingate (2003)	353.5	41.2
	Warakurna LIP grand mean					*28*			*35.3*	*4.7*			*32.2*	*105.2*	*This study*	*348.2*	*48.6*

Note: The first column gives identification number (see Fig. S1), the second column gives the site names, the third and fourth columns give the site latitudes and longitudes, the fifth and sixth columns give the stratum dip directions and dips for rocks with paleohorizontal indicators, the seventh column gives the number of directions, the eighth and ninth columns give the geographic (i.e., in situ) declination and inclination of the Fisher mean directions, the tenth column gives the estimates of the Fisher precision parameter, the eleventh column gives the semiaxes of the 95% confidence interval for the mean direction, the twelfth and thirteenth columns give the tilt-corrected declination and inclination of the Fisher mean directions (where applicable), the fourteenth and fifteenth columns give the latitude and longitude of the associated virtual geomagnetic pole (VGPs) that have been variably tilt-corrected following the VGPs used in Wingate et al. (2002), Wingate (2003), and Wingate et al. (2004), the sixteenth column gives the references for the data, and the seventeenth and eighteenth columns give the directions of the VGPs calculated for local Jack Hill coordinates (i.e., at Erawandoo Hill).

Table S4. Universal Transverse Mercator GPS coordinates for the sampling sites in Fig. S2 and in Weiss et al. (2015) Fig. 1. Datum surface is the World Geodetic System 1984, zone 50S.

Name	Easting (m)	Northing (m)	Reference	Original System	Notes
EHJH5	499084	7105804	Weiss et al. (2015)	AGD84	Pebble conglomerate tests Hadean (i.e., >4 Ga) discovery site on Erawandoo Hill
EHJH6,7	499131	7105844	Weiss et al. (2015)	AGD84	Pebble conglomerate test Hadean discovery site on Erawandoo Hill
01JH54	499137	7105849	Cavosie et al. (2004)	WGS84, 50S	Hadean detrital zircon site
01JH63	499153	7105793	Cavosie et al. (2004)	WGS84, 50S	Proterozoic detrital zircon site
01JH65	499109	7105839	Cavosie et al. (2004)	WGS84, 50S	Hadean detrital zircon site
01JH32	499626	7106365	Cavosie et al. (2004)	WGS84, 50S	
01JH33	499692	7106380	Cavosie et al. (2004)	WGS84, 50S	
01JH36	499947	7106428	Cavosie et al. (2004)	WGS84, 50S	Hadean detrital zircon site
JH1	498989	7105703	Dunn et al. (2005)	AGD94	Hadean detrital zircon site
JH2	499134	7105827	Dunn et al. (2005)	AGD94	Hadean detrital zircon site
JH3	499488	7105908	Dunn et al. (2005)	AGD94	Hadean detrital zircon site Proterozoic detrital zircon site
152	498140	7105889	Grange et al. (2010)	WGS84	Hadean detrital zircon site Proterozoic detrital zircon site
154	498694	7105949	Grange et al. (2010)	WGS84	
JT10	498835	7106156	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JT8,9	498827	7106151	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC16	498664	7106089	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC15	498658	7106088	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC17	498635	7106079	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC14	498610	7106074	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC13	498607	7106064	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC12	498592	7106065	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC11	498585	7106063	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC19	498567	7106057	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC18	498563	7106055	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC21	498557	7106051	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC20	498550	7106046	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC10	498544	7106014	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC9	498544	7105993	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC1	498539	7106007	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC25	498532	7106007	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC22	498526	7106002	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC23	498527	7105999	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC2	498523	7105998	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC24	498520	7105998	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC8	498517	7105993	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC3a,b	498512	7105993	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test

JC4	498509	7105987	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC5	498488	7105983	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
JC6	498489	7105980	Tarduno and Cottrell (2013)	WGS84	Cobble conglomerate test
W74	499137	7105850	Weiss et al. (2015)	WGS84, 50S	Hadean zircon discovery site on Erawandoo Hill
BC	499336	7105897	Weiss et al. (2015)	WGS84, 50S	Dolerite baked contact test
BCB	499320	7105890	Weiss et al. (2015)	WGS84, 50S	Dolerite baked contact test
Blob4	496529	7105176	Weiss et al. (2015)	WGS84, 50S	Monzogranite
Blob5	496628	7105250	Weiss et al. (2015)	WGS84, 50S	Monzogranite
D102	499952	7106439	Weiss et al. (2015)	WGS84, 50S	Fold test
D107	499498	7106336	Weiss et al. (2015)	WGS84, 50S	Cobble conglomerate test
D108	499450	7106321	Weiss et al. (2015)	WGS84, 50S	Cobble conglomerate test
D109	499371	7106303	Weiss et al. (2015)	WGS84, 50S	Cobble conglomerate test
D110	499337	7106296	Weiss et al. (2015)	WGS84, 50S	Cobble conglomerate test
D111	499056	7106301	Weiss et al. (2015)	WGS84, 50S	Cobble conglomerate test
D112	499059	7106244	Weiss et al. (2015)	WGS84, 50S	Cobble conglomerate test
D145	499232	7106174	Weiss et al. (2015)	WGS84, 50S	Quartzite
D154	499104	7105946	Weiss et al. (2015)	WGS84, 50S	Dolerite baked contact test
D182	496471	7105181	Weiss et al. (2015)	WGS84, 50S	Monzogranite
D183	496466	7105187	Weiss et al. (2015)	WGS84, 50S	Monzogranite
D184	496453	7105202	Weiss et al. (2015)	WGS84, 50S	Monzogranite
D185	496436	7105210	Weiss et al. (2015)	WGS84, 50S	Monzogranite
D186	496419	7105209	Weiss et al. (2015)	WGS84, 50S	Monzogranite
D187	496412	7105209	Weiss et al. (2015)	WGS84, 50S	Monzogranite
D188	496375	7105205	Weiss et al. (2015)	WGS84, 50S	Monzogranite
D189	496346	7105208	Weiss et al. (2015)	WGS84, 50S	Monzogranite
D192	498741	7106132	Weiss et al. (2015)	WGS84, 50S	Quartzite
D194	498087	7105820	Weiss et al. (2015)	WGS84, 50S	Quartzite
D195	497834	7105628	Weiss et al. (2015)	WGS84, 50S	Quartzite
D197	497715	7105472	Weiss et al. (2015)	WGS84, 50S	Fold Test
DOL1	499266	7105894	Weiss et al. (2015)	WGS84, 50S	Dolerite
DOL2	499268	7105896	Weiss et al. (2015)	WGS84, 50S	Dolerite
DOL5	499339	7105868	Weiss et al. (2015)	WGS84, 50S	Dolerite
DOL6	499326	7105853	Weiss et al. (2015)	WGS84, 50S	Dolerite
W025	498575	7106095	Weiss et al. (2015)	WGS84, 50S	Cobble conglomerate test
W026	498622	7106113	Weiss et al. (2015)	WGS84, 50S	Cobble conglomerate test

Note: First column gives the site name, the second column gives the northing, the third column gives the easting, the fourth column gives the reference, the fifth column gives the original datum (AGD84 = Australian Geodetic Datum 1984 and WGS84 = World Geodetic Datum 1984) in which the site coordinates were measured in the field [for Weiss et al. (2015)] or reported (for other studies), and the final column gives additional site information. Site coordinates for all sites other than those of Weiss et al. (2015) were gleaned from published papers and were not provided formally approved by those authors. Transformations between geographic and Universal Transverse Mercator coordinate systems with different datum planes introduce some position error, but all points listed in this table should be within 2 m of the published locations.

Supplementary References

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